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Factors influencing construction ergonomic performance in India

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Abstract

Many construction industry sectors have been experiencing chronic problems, such as poor management of workforce, improper working conditions, tools, and working methods. Many researchers have identified these problems as factors that affect construction productivity and overall ergonomic performance of the workers. Keeping in view the necessity of addressing problems as stated, a questionnaire-based survey was conducted to study the critical issues related to the workers involved in man-machine interaction at the construction sites. This research has identified the quantified RIIs, determined the influence ranks of 30 factors affecting construction ergonomic performance in India. These factors were classified under the following three primary classifications: (a) human/labor related factors; (b) tasks-related factors; and (c) equipment/tools-related factors based on various age groups and occupations of the construction workers. Industry practitioners and researchers can use the primary outcomes of this study in developing systems to enhance and improve health and safety of the construction workers for effective management of construction labor workforce and to achieve a competitive level of quality and a cost-effective project.

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*Keywords:*Ergonomic performance, Construction worksystem, Man-machine interaction, Relative Importance Index (RII), Risk factors

1. Introduction

In many occupations particularly in construction, workers are often exposed to extreme environmental conditions. In a peripatetic construction worksystem, the workers usually work in an open environment under adverse environmental conditions, such as thermal and cold stress, insufficient illumination, loud noise, hand-arm vibration, etc. The large variations in the environment may cause various health injuries, thereby reducing the

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inherent productivity of the workers. Since the construction labors are the most dynamic element in the construction industry and their cost represents almost half of the overall construction cost [1, 2, 3], improving ergonomic performance of the workers has become a target for construction companies in India as it may also contribute to the development of cumulative trauma disorders (CTDs) hampering significantly the productivity of the workers as reported in many case studies. Therefore, in order to assess the effect of environment on the performance of worker, the extent of risk associated with the manual handling of tools/equipment, details of the tools and equipment and related issues while workers are engaged in construction jobs in this context, appropriate ergonomic principles are required to be applied to minimize the health hazards for ensuring safety and comfort of the workers [4].

2. Ergonomic issues in construction

As per the data available in 1999, out of the total population in India (936,546,000), approximately 315 million people are labourers and out of which 94 million people are construction workers as and when compared with USA which has nearly 10 million people engaged in construction [5]. In India, workers are facing a lot of health problems because of severe Manual Material Handling (MMH) activities at the workplace and the factory act, 1948, does not indicate any safe load limit for Indian population. Unlike developed countries, construction-related data on hazards and fatality are very few and are not available for Indian workers [6,7]. As there is dearth of literature in this sector [8] and research is very limited in this industry despite of high prevalence of MSDs [9, 10], there is a need for an in-depth study (laboratory study as well as field evaluation) of the construction sites [11].

Researchers pointed out that there is lack of studies in construction worksystem, presumably because of high task variability, irregular work periods, changing work environments, and the transient nature of construction occupations[1, 12]. Also, in highly physically demanding construction jobs, psychosocial and physical work-related factors are the most important factors associated with work ability. As construction work varies depending on site conditions, type of building, differences in worksystem, variation in work methods and other factors, these differences could either increase or decrease workers exposure to various occupational risk factors [13], such as slips and trips that depend on several contributing factors such as work conditions, working surfaces, environmental conditions, etc. [14].

The physically demanding nature of the construction trade have made it more risky for the workers affecting their health. This has been extensively studied by Holmström et al. and Zimmermann [15, 16]. Campbell has pointed out that construction industry have become more stressful in recent years [17]. The construction industry consists of many jobs each with its own specific demands for requirements. The need for recovery after work is a sign of occupationally-induced fatigue and a predictor of adverse health effects [18]. In order to address the serious issue of construction workers, five important research issues are considered in this study for identifying the factors influencing ergonomic performance of MMH tasks at the construction sites. The research issues are as follows: Issue-1: Characteristics of MMH Tasks, Issue-2: Features of the Working Environment, Issue-3: Types of MMH Activities and their Characteristics, Issue-4: Characteristics of the Jobs/Tasks, and Issue-5: Types of Tools and Equipment used. The information on several characteristics of construction-related MMH jobs/tasks are asked for as actual characteristics (methods as well as types of interfaces) of such jobs/tasks are dependent on a number of factors, such as job knowledge, experience, training, work conditions and risks.

3. Study methodology

Keeping in view the necessity of addressing problems as stated, a questionnaire-based survey was conducted and primary data for ergonomic design and analysis of the MMH tasks/jobs at construction sites were collected from a brown-field construction site at a steel plant in Eastern region of India that addresses a number of relevant five research issues related to the workers involved in man-machine interaction at the construction sites as mentioned. These research issues are considered to be essential for a comprehensive review of worksystem dimensions and components at the construction sites. Data were collected through the survey are required for identifying and properly assessing the risk factors associated with various MMH activities for which biomechanical, physiological and physical evaluations are necessary. Furthermore, based on the responses, the contribution of each of the factor

influencing construction ergonomic performance were examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was found by Relative Importance Index (RII) which is as follows:

$$\text{RII} = \frac{\Sigma W}{A \times N} (0 \leq RII \leq 1)$$

where, W = Weight given to each factor by the respondents
A = Highest weight
N = Total number of respondents

4. Data analysis

It has been observed that the risk of musculoskeletal injuries/disorders appeared to be highest among mason helpers as compared to other occupations because they suffer from pain in almost the joints and the risk factors are also critical and versatile in nature, masons are rated as the second highest occupation facing a number of problems due to the peripatetic nature of construction-related MMH activities and highly correlated to the causes of MSDs, and apart from masons and mason helpers, carpenters also suffer from pain that causes a number of MSDs among them because they are also highly involved in MMH activities. In this context, mason, mason helpers and carpenters were selected for the study in order to find out the important factors affecting their performance.

For analysis purpose, data pertinent to the characteristics of MMH tasks, features of the working environment, types of MMH activities and their characteristics, characteristics of the jobs/tasks, and types of tools and equipment used are collected from a sample of 220 construction workers out of which 49 are masons, 84 are mason helpers and 87 are carpenters. In all the occupations considered, there are female workers only working as a helper to the mason as they are around 10% of total number of mason helpers. It is found that 40% of the masons and carpenters are between the age group of 25-34 years and 30% are less than 25 years. As has been found, 40% of the mason workers are below 25 years of age and most of them are between 25-34 years of age. Depending on the criticality of their work, the workers work around more than 8 hours with three to four hours of overtime in both (open and closed) environments.

To improve construction ergonomic performance, it is essential to identify and recognize the influence of the primary factors affecting ergonomic performance of the construction workers leading to a number of musculoskeletal disorders. The perceived effect of each of the 30 factors is determined. The overall factors are classified under three major categories viz. (a) human/labor related factors; (b) tasks-related factors; and (c) equipment/tools-related factors based on various occupations of the construction workers. The ranks and RII's of the factors are presented and discussed in the following sections.

The relative importance indices and ranks of the 14 factors classified under human/labour-related factors are shown in Table 1 and 2. Table 3 shows task-related factors and Table 4 depicts tools/equipment-related factors.

Table 1.RII and Ranking of Factors in Human/labour-related Category (Level of Discomfort in Various Body Joints).

Sl. No.	Human/labor related factors (Level of Discomfort in Various Body Joints)	Masons		Mason Helpers		Carpenters	
		RII	Rank	RII	Rank	RII	Rank
1	Neck	0.95	2	0.53	5	0.84	2
2	Shoulder	0.93	3	0.77	2	0.76	3
3	Elbow	0.89	5	0.74	3	0.76	4
4	Wrist	1	1	0.72	4	0.74	5
5	Knuckle	0.4	6	0.20	6	0.29	6
6	Spine	0.92	4	0.89	1	0.89	1

Table 2.RII and Ranking of Factors in Human/labour-related Category (Level of Discomfort in Various Body Movements).

Sl. No.	Human/Labor related factors (Level of Discomfort in Various Body Movements)	Mason		Mason Helpers		Carpenters	
		RII	Rank	RII	Rank	RII	Rank
1	Bending	0.90	3	0.98	1	0.99	1
2	Squatting	0.67	7	0.73	4	0.99	2
3	Standing	0.85	5	0.81	3	0.92	4
4	Streching	0.71	6	0.71	5	0.98	3
5	Suddenly Changing Position	0.56	8	0.69	6	0.86	6
6	Twisting	0.93	1	0.83	2	0.76	8
7	Kneeling	0.91	2	0.59	8	0.89	5
8	Stooping	0.87	4	0.60	7	0.85	7

Table 3.RII and Ranking of Factors in Task-related Category.

Sl. No.	Tasks-related factors	Mason		Mason Helpers		Carpenters	
		RII	Rank	RII	Rank	RII	Rank
1	Methods of work	0.5	10	0.67	7	1	1
2	Work load	1	1	0.72	6	1	2
3	Repetitive work	1	2	0.52	10	1	3
4	Lack of rest	0.90	6	0.95	2	1	4
5	Climate/environment	0.90	7	0.58	8	0.59	9
6	Awkward posture	0.92	5	0.75	5	0.74	8
7	Static Posture	0.65	8	0.92	4	0.93	7
8	Strenuous Task	1	3	1	1	1	5
9	Physically tired	1	4	0.92	3	1	6
10	Overall discomfort-level (after 2 hours of work period)	0.58	9	0.58	9	0.58	10

Table 4.RII and Ranking of Factors in Equipment/tools-related Category.

Sl. No.	Equipment/tools-related factors	Mason		Mason Helpers		Carpenters	
		RII	Rank	RII	Rank	RII	Rank
1	Tools/equipment	0.54	6	0.72	2	0.98	1
2	Equipment heavy to handle	0.80	4	0.67	5	0.67	5
3	Difficulty in grasping	0.60	5	0.55	6	0.55	6
4	Handles to grasp	0.88	2	0.72	4	0.71	4
5	Accident while using a hand tool	1	1	0.79	1	0.78	2
6	PPE create difficulty/obstruction	0.87	3	0.72	3	0.71	3

5. Results and discussions

Relative Importance Index (RII) was calculated for each of the factors so that the important and critical factors may be identified and proper preventive and remedial measures could be taken up. Table 1 shows the level of discomfort in various body joints (human-related). The most critical joints that create discomfort among masons are wrist, neck, shoulder, spine, etc. However, mason helpers face pains in their spine mostly and then shoulder, elbows, etc. due to repetitive carrying materials, such as bricks, sand, mortar, etc. from one place to another.In other way, carpenters feel pain in their spine, neck and shoulders due to stretching and standing position.

Table 2 shows the level of discomfort due to various body movements. Bricklaying is one of the major tasks being done by the mason that leads to several awkward body movements, such as twisting, kneeling, bending, stooping, etc. Similarly, helpers remaining associated with masons, welders, gas cutters, carpenters and rod binders, basically carry out repetitive and strenuous tasks, such as preparation of mortar (mixture of sand and cement or cement and concrete chips) with the help of shovel, lifting and carrying mortar with kadai or cement bags, lifting and placing reinforcement concrete cement (RCC) bricks above shoulder height, sieving sand from gravels, house-keeping, brick loading and unloading, transfer of oxygen cylinders with the help of a trolley, manually carrying voilers, tie rods, hammering, L-shaped rods, wooden planks, H-beams, towers and bracings from one place to another, pulling of rope to lift nuts and bolts, C-clamps, metal sheets at heights through rope pulley, etc. It has been observed that mason helpers basically undergo body movements like bending, twisting, standing, squatting, etc. Carpenters are basically involved with a number of MMH tasks, such as cutting of wooden planks with proper shape and size as per the structure, providing ‘jacks’ or vertical support for preparing wooden frame structure, nailing wooden planks, and providing and anchoring side supports with nails. The tools being used by the carpenters are hand saw, hammer, chisel, iron claw, cutting pliers, right angle triangle, spirit level, plumb, pencil, nails, measuring tape, wooden planks, steel jack, galvanized iron (GI) wire and folding wooden tape. This leads to bending,squatting, stretching, standing, etc. body movements ultimately leading towards severe and intolerable pain.

Table 3 discusses task-related category wherein masonsmostly get physically tired due to heavy, strenuous and repetitive workload. They also assume awkward posture to carry out their work whenever there is a space constraint. In other context, ground-level workers carry materials from one place to other which becomes strenuous for them. Carrying out such work for long 8 hours make them highly tired. Due to prevailing manualness in construction, methods of work, workload, repetitive work and lack of rest affect them mostly. In all cases, the foremost important factor is accident while using a tool/equipment and due to anthropometric mismatch, it becomes difficult for them to grasp the tool or equipment as given in Table 4.

6. Conclusions

As each construction occupation and task represents a unique situation, identification and application of preventive measures, tools and proper work conditions may be best derived from occupations and task-specific MMH studies. It is crucial and important to mention that ergonomic interventions are required to be implemented on a priority basis for maintaining the work ability among workers and minimize the incidence of injuries and accidents in various construction occupations [19, 20].

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References

[1] Rivas, R. A., Borcherding, J. D., González, V. and Alarcón, L. F., Analysis of Factors Influencing Productivity Using Craftsmen Questionnaires: A Case Study in a Chilean Construction Company, Journal of Construction Engineering and Management, 137, (2011), 312-320.
[2] Harmon, K. M., and Cole, B., Loss of productivity studies–Current uses and misuses, Constr. Briefs., 8, (2006), 1–19.
[3] Hanna, A. S., Taylor, C. S., and Sullivan, K. T., Impact of Extended Overtime on Construction Labor Productivity, Journal of Construction Engineering and Management 131, (2005), 734-739.
[4] Parida, R. and Ray, P. K., A Comprehensive Framework for Physical Evaluation of Manual Material Handling Tasks, International Journal of Manufacturing Technology and Management, 24, (2011), 153-166.
[5] Kaming, P.F., Olomolaiye, P.O., Holt, G.D. and Harris, F.C., Regional Comparison of Indonesian Construction Productivity, Journal of Management in Engineering,, 13, (1997), 33-39.
[6] Maiti, R. and Ray, G.G., Determination of maximum acceptable weight of lift by adult female workers. International Journal of Industrial Ergonomics, 34, (2004), 483-495.
[7] Mehta, A.A., Mehta, K.A., Parmar, S.A. and Mehta, A.K., A survey on injuries in workers and impact of safety measures on construction work-related injuries in India, Case study case report, 1, (2011), 9-19.
[8] Van der Molen, H.F., Suilter, J.K., Hulshof, C.T.J., Vink, P., van Duivenbooden, C. and Frings-Dresen, M.H.W., Conceptual framework for the implementation of interventions in the construction industry, Scandinavian Journal of Work, Environment and Health, 31, (2005), 96-103.
[9] Forde, M.S. and Buchholz, B., Task content and physical ergonomic risk factors in construction iron work, International Journal of Industrial Ergonomics, 34, (2004), 319–333.
[10] Sillanpää, J., Lappalainen, J., Kankiainen, A., Viljanen, M. and Laippala, P., Deceasing the physical workload of construction work with the use of four auxillary handling devices, International Journal of Industrial Ergonomics, 24, (1999), 211-222.
[11] Hsaio, H. and Stanevich, R.L., Injuries and ergonomic applications in construction, In: Occupational Ergonomics: Theory and Applications, Taylor and Francis, (2011), 629-651.
[12] Kisner, S. M. and Fosbroke, D. E., Injury hazards in construction industry. Journal of Occupational Medicine, 36, (1994), 137-143.
[13] Spielholz, P., Davis, G. and Griffith, J., Physical risk factors and controls for musculoskeletal disorders in construction trades, Journal of Construction Engineering and Management, 132, (2006), 1059- 1068.
[14] Lipscomb, H. J., Glazner, J. E., Bondy, J., Guarini, K. and Lezotte, D., Injuries from slips and trips in construction, Applied Ergonomics, Vol. 37, (2006), 267-274.
[15] Holmstrom, E., Lindell, J., and Moritz, U., Healthy lower backs in the construction industry in Sweden, Work and stress, 7, (1993), 259-271.
[16] Zimmermann, C.L., Rosecrance, J.C., Cook, T.M. and Schneider, S.P., Construction, In: Karwowski, W., International Encyclopedia of Ergonomics and Human Factors, Taylor and Francis, III, (2001), 1486-1488.
[17] Campbell, F., Occupational Stress in the Construction Industry, Chartered Institute of Building (CIOB), (2006).
[18] Sluiter, J.K., van der Beek, A.J., and Frings-Dresen, M.H, The influence of work characteristics on the need for recovery and experienced health: a study on coach drivers, Ergonomics, 42, (1999), 573–583.
[19] Alavinia, S.M., van Duivenbooden, C. and Burdorf, A., Influence of work-related factors and individual characteristics on work ability among Dutch construction workers, Scandinavian Journal of Work, Environment and Health, 33, (2007), 351-357.
[20] Forbes, L. H., Industrial engineering applications in the construction industry, In: Handbook of Industrial and System Engineering, (2006), 31-37, Taylor and Francis, London.